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(54) Dielectric resonator antenna with wide bandwidth.

(57) The invention relates to a dielectric resonator antenna system which exhibits an unusually wide bandwidth. This is achieved by choosing a patch antenna/dielectric resonator combination with shape and dimensions such that resonance modes over a continuous range wavelengths can be established therein. The bandwidth and transmission properties of the device are further improved by including a dielectric coupling element (between the dielectric resonator and air) whose antireflection characteristics are optimised for a wavelength which is slightly different from the maximum wavelength of the patch antenna.

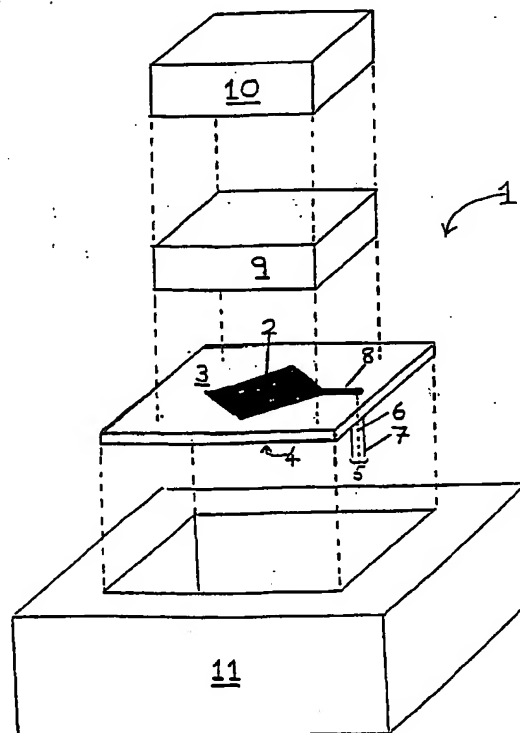


FIGURE 2

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This invention relates to a dielectric resonator antenna system with wide bandwidth and, in particular but not exclusively to, such a system for use as an element in a phased array.

The dielectric resonator antenna is well known. It may be probe fed (eg S A Long, M W McAllistar and L C Shen; IEEE Transactions on Antennas and Propagation AP-31, No 3, May 1983, pp406-412 and S A Long and M W McAllistar; International Journal of Infrared and Millimetre Waves, 7, No4, 1986, pp550-570) where the probe has length approximately equal to one quarter of the operating wavelength, and is used to excite a fundamental mode in a coupling block which takes the form of a dielectric puck. The dimensions of the puck are such that it resonates at a specific frequency, this frequency being determined, to a large extent, by the overall volume of the puck.

Alternatively the coupling block may be excited using a patch antenna formed from microstrip, a form of waveguide comprising a copper strip separated from a groundplane by a dielectric substrate. The copper strip is etched to leave an antenna of the required shape and size, typically a square patch fed at the centre of one edge and with the length of each edge equal to half the operating wavelength. Such antennae have the advantage that they occupy little space and can be conveniently connected to form thin planar arrays.

In an array, each element has its own input and output and by varying the phase of the signal at each element the array can be arranged to transmit or receive in a chosen direction. Moreover the chosen direction can be made time dependant so that a given field can be scanned.

At the interface between the coupling block and air, some of the signal is reflected rather than transmitted. This loss of power can be minimised by including an antireflection layer between the dielectric layer and the air (eg British Patent Publication no. GB 2 248 522 A). In order to minimise reflection between two media, the thickness of the antireflection layer should approximate to a quarter wavelength of the signal being transmitted. In addition the material of the antireflection layer should (in theory) have a dielectric constant which approximates to the geometric mean of the dielectric constants of the media on either side. In practice, considerable departure from this ideal is acceptable: for example for matching between air (dielectric constant = 1) and a coupling block of material with dielectric constant = 10, the ideal matching material would have a dielectric constant of 3.16. In practice it is found that polymethylmethacrylate with a dielectric constant of 2.4 serves adequately as a matching material.

Although the foregoing configurations are relatively simple, their use is limited by the inherently

narrow range of frequencies over which they can be operated (ie their inherently narrow bandwidth). For example, H LI and C H CHEN describe a probe fed antenna with bandwidth of approximately 200 MHz at 20 dB in Electronics Letters vol. 26 No. 24 (22 November 1990) pp2015-2016. The object of this invention is to provide a dielectric resonator antenna with wide bandwidth.

According to this invention the bandwidth of a dielectric resonator antenna is greatly enhanced by an appropriate choice of shape for the exciting patch. Specifically it has been shown that if a patch is chosen whose length varies along its width, then a wide range of resonant frequencies can be stimulated therein. Furthermore it has been shown that by employing an antireflection block whose optimum frequency is close to, but slightly different from, the minimum frequency of the patch (typically 5% less), the bandwidth and transmission properties of the device are further improved.

According to this invention, a dielectric resonating antenna system comprises

- a dielectric substrate sheet having opposing first and second surfaces;
- a patch antenna formed on the first surface, the patch antenna having a length that varies across the width of the patch such that a wide range of resonant frequencies can be stimulated therein;
- a ground plane formed on the second surface;
- means for feeding signals to and, or from the patch antenna and
- a dielectric coupling element adjacent to the first surface whose dielectric constant and dimensions are such that radiation coupling to and from the patch antenna is predominantly through itself.

In a preferred embodiment, the antenna takes the form of a square, corner-fed patch which is formed on microstrip using the same photo-etching techniques that are standard for making other microwave integrated circuits. An additional advantage of this configuration is that it readily lends itself to implementation of orthogonal planes of polarization by including a second means for feeding signals to and, or from the patch. Other shapes of patch antenna may also provide these properties of enhanced bandwidth and facilitation of orthogonal planes of polarization.

The preferred means for feeding signals to and, or from the patch antenna is via a coaxial feed through the groundplane and dielectric substrate.

An additional preferred embodiment includes a dielectric antireflection layer whose dimensions are chosen to provide quarter wavelength antireflection characteristics for an optimum wavelength which is slightly different from the maximum operating

wavelength of the patch antenna.

These components may be enclosed in an open-ended metal cavity which constrains the radiating field to that of an aperture rather than a volume. The dimensions of the cavity may be such that a space (air gap) remains between the coupling element and the cavity wall and/or between the dielectric substrate sheet and the cavity wall.

Embodiments of the device will now be described, by way of example only, with reference to the accompanying diagrams in which :-

Figure 1 is an example of the shape of antenna which provides the wide bandwidth properties of the invention.

Figure 2 is an exploded view of a typical antenna system of the invention in disassembled form.

Figures 3a, 3b and 3c show the component parts making up a four element sub-array, where each element comprises an antenna system of the invention.

Figure 3d shows a cross-section of the sub-array assembly. Larger arrays (typically around 2000 elements) are formed by combining a number of sub-arrays such as this.

Figure 4 shows part of an array of patch antennas of the invention with the implementation of orthogonal planes of polarisation.

Figure 5 shows the range of frequencies over which a typical antenna system of the invention was found to be useful.

Figure 6 shows the E-plane and H-plane radiation patterns obtained from a typical antenna system of the invention.

Figure 1 shows a square, corner fed patch antenna 2, fed by a planar feed 8. In this orientation, the maximum value of the 'X' dimension of the patch is  $x_1$  between opposite corners of the antenna. As the line through which this dimension is taken moves in the 'Y' direction away from this starting point, the value of the 'X' dimension decreases through intermediate values  $x_n$  to zero at the points a and b. Thus the length of the patch (in the 'X' direction) varies across its width (in the 'Y' direction).

Figure 2 shows an antenna system 1 of the invention. An antenna of microstrip construction takes the form of a square planar corner-fed patch 2 mounted on a dielectric layer 3. A ground plane 4 clads the underside of the dielectric layer 3. A coaxial radio frequency feedthrough 5 has an inner conductor 6 and an outer shield 7. The inner conductor 6 is insulated from the dielectric layer 3 and is connected to a planar feed 8 into the corner of the patch antenna 2. The outer shield 7 is connected to the ground plane 4.

A dielectric coupling block 9 is located flush against the patch antenna 2 and the top side of the

dielectric layer 3. This block 9 is present for radiation purposes and is of PT10, a proprietary material manufactured by Marconi Electronic Devices Ltd., a British company. It is composed of a mixture of alumina and titanium dioxide ceramic materials bound by polystyrene and has a dielectric constant of 10. The thickness of the coupling block approximates to one quarter of the centre frequency of the patch antenna and its overall dimensions are chosen to provide optimum resonance at that frequency.

A second dielectric block 10 is located flush against the top side of the coupling block 9. This second block 10 is present for antireflection purposes and is of polymethylmethacrylate with a dielectric constant of 2.4. It has thickness approximately equal to, but different from, one quarter of the maximum wavelength of the patch antenna.

The dielectric coupling block 9 is bonded to the dielectric layer 3 and the antireflection block 10 using common household glue.

The assembly of the dielectric substrate 3 with ground plane 4 and patch antenna 2, dielectric coupling block 9 and dielectric antireflection block 10, are held within an open-ended metal cavity in the form of casing 11. The particular mode or modes of resonance set up in dielectric coupling block 9 depends on whether the block 9 is in contact with the metal cavity wall or, as shown here and in figure 3d, there is a gap between the two. It has been found that the best radiation patterns are obtained when a gap of at least 1.5mm is present all round the block 9. Moreover, if a similar gap (not shown) is present between the substrate 3 and the cavity wall then the interaction between the feed line 8 and the metal surround can be minimised.

Figure 3a shows a plan view of an array 12 of four square-planar corner-fed patch antennas 2 on a dielectric substrate 3. The underside of the substrate 3 is clad by a copper groundplane (not shown). Holes 13 accommodate retaining screws (not shown).

Figure 3b shows a brass backplate 14 which is assembled flush against (and in electrical contact with) the groundplane of the dielectric substrate 3 shown in figure 3a. Holes 13 are tapped to accommodate retaining screws (not shown). Holes 15 each accommodate a coaxial feedthrough (not shown). The inner conductors of these feedthroughs are insulated from the brass backing plate 14, the dielectric substrate 3 and groundplane, and pass through these to connect with the planar feeds 8 shown in figure 3a. The outer shields of the coaxial feedthroughs are connected to the brass backing plate 14.

Figure 3c shows an aluminium alloy block 11 which is mounted on top of the dielectric substrate

shown in figure 2a. Four windows 10 are of transparent polymethylmethacrylate and are present for antireflection purposes. Sandwiched between each window 10 and the corresponding patch antenna 2 on the dielectric substrate 3 is a dielectric coupling block of PT10 material (not shown). The holes 13 accommodate retaining screws (not shown).

Figure 3d shows a cross section of an assembly of the components of figures 3a, 3b and 3c. Dielectric coupling blocks 9 and their relationship with the other components are shown. The plane of the section passes through coaxial feedthroughs 5 with inner conductors 6 and outer shields 7. The inner conductors 6 are insulated from, and pass through, the brass backing plate 14 and dielectric substrate 3 and are connected to the planar feeds into the patch antennas (not shown). The outer shields 7 are connected to the brass backing plate 14 only.

Figure 4 shows a dielectric substrate 3 with an array 12 of patch antennas similar to that shown in figure 2a but with the ability to implement orthogonal planes of polarisation. This is achieved by including a second planar feed 8a on each patch antenna. Planar feeds 8 and 8a feed adjacent corners of each patch.

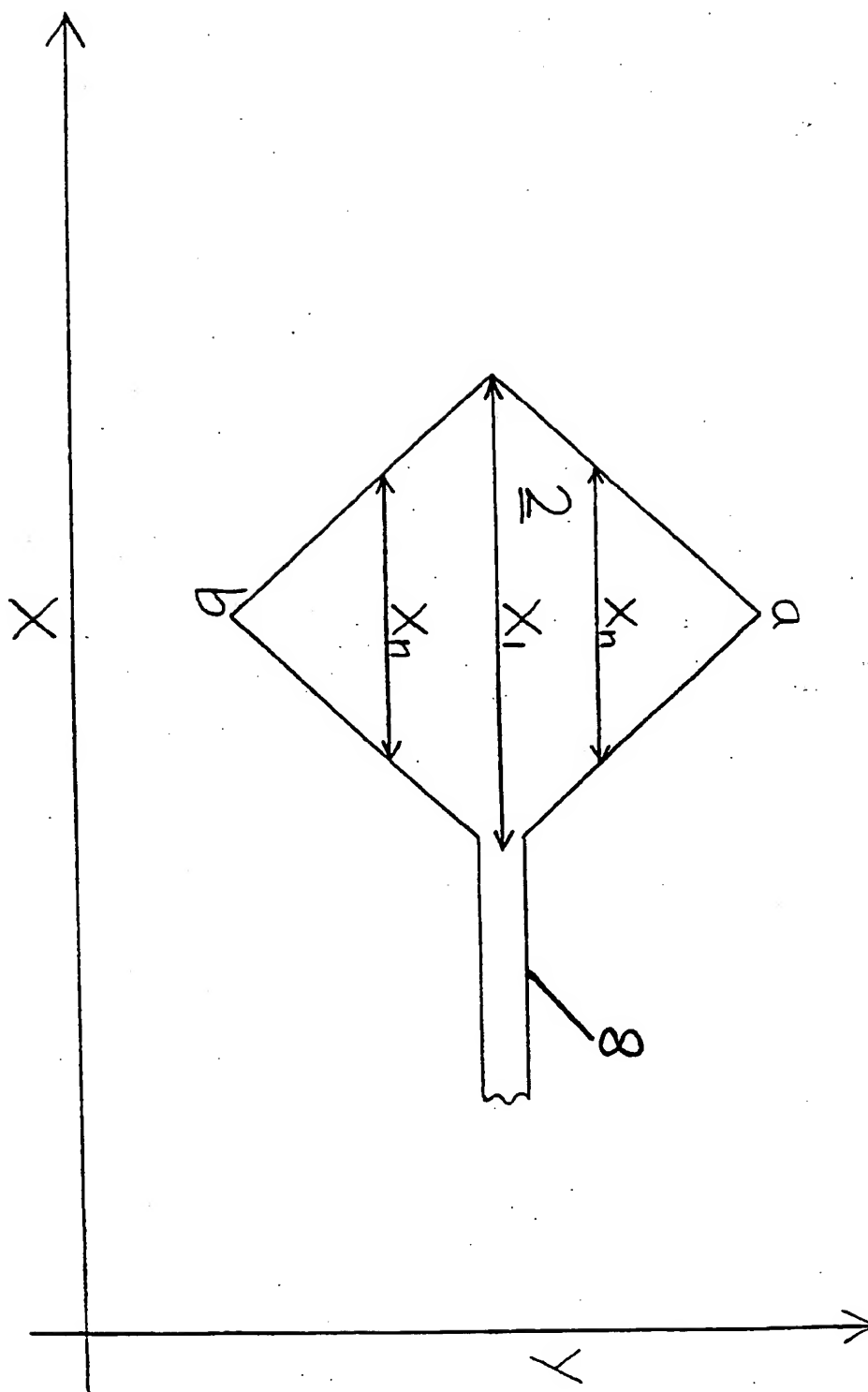
Figure 5 is a typical linear plot of the match which can be obtained from the type of antenna system described above. The vertical axis indicates power which is reflected back along the transmission line rather than being transmitted into free space. The diagram shows the variation of this power with signal frequency and a useful bandwidth of about 2 GHz at 20 dB.

Figure 6 shows typical E-plane and H-plane radiation patterns obtained from this type of antenna system for a signal frequency of 9.6 GHz.

## Claims

1. A dielectric resonator antenna system comprising
  - a dielectric substrate sheet having opposing first and second surfaces;
  - a patch antenna formed on the first surface, the patch antenna having a length that varies across the width of the patch such that a wide range of resonant frequencies can be stimulated therein;
  - a ground plane formed on the second surface;
  - means for feeding signals to and, or from the patch antenna and
  - a dielectric coupling element adjacent to the first surface whose dielectric constant and dimensions are such that radiation coupling to and from the patch antenna is predominantly through itself.
2. The dielectric resonator antenna system of claim 1 where the patch antenna is square and corner fed.
3. The dielectric resonator antenna system of claim 1 or 2 with the addition of a second means for feeding signals to and, or from the patch.
4. The dielectric resonator antenna system of claims 1, 2 or 3 where the means for feeding signals to and, or from the patch antenna comprises a coaxial cable.
5. The dielectric resonator antenna system of any one of the preceding claims with the additional feature of a dielectric matching element whose antireflection characteristics are optimised at a wavelength which is slightly different from the maximum operating wavelength of the patch antenna.
6. The dielectric resonator antenna system of any one of the preceding claims where the components are enclosed in an open-ended metal cavity.
7. The dielectric resonator antenna system of claim 6 where an air gap is included between the dielectric coupling element and the cavity wall.
8. The dielectric antenna system of claim 6 or 7 where an air gap is included between the dielectric substrate and the cavity wall.
9. An array of patch antennae elements, each element comprising a dielectric resonator antenna system as claimed in any of the preceding claims.

FIGURE 1



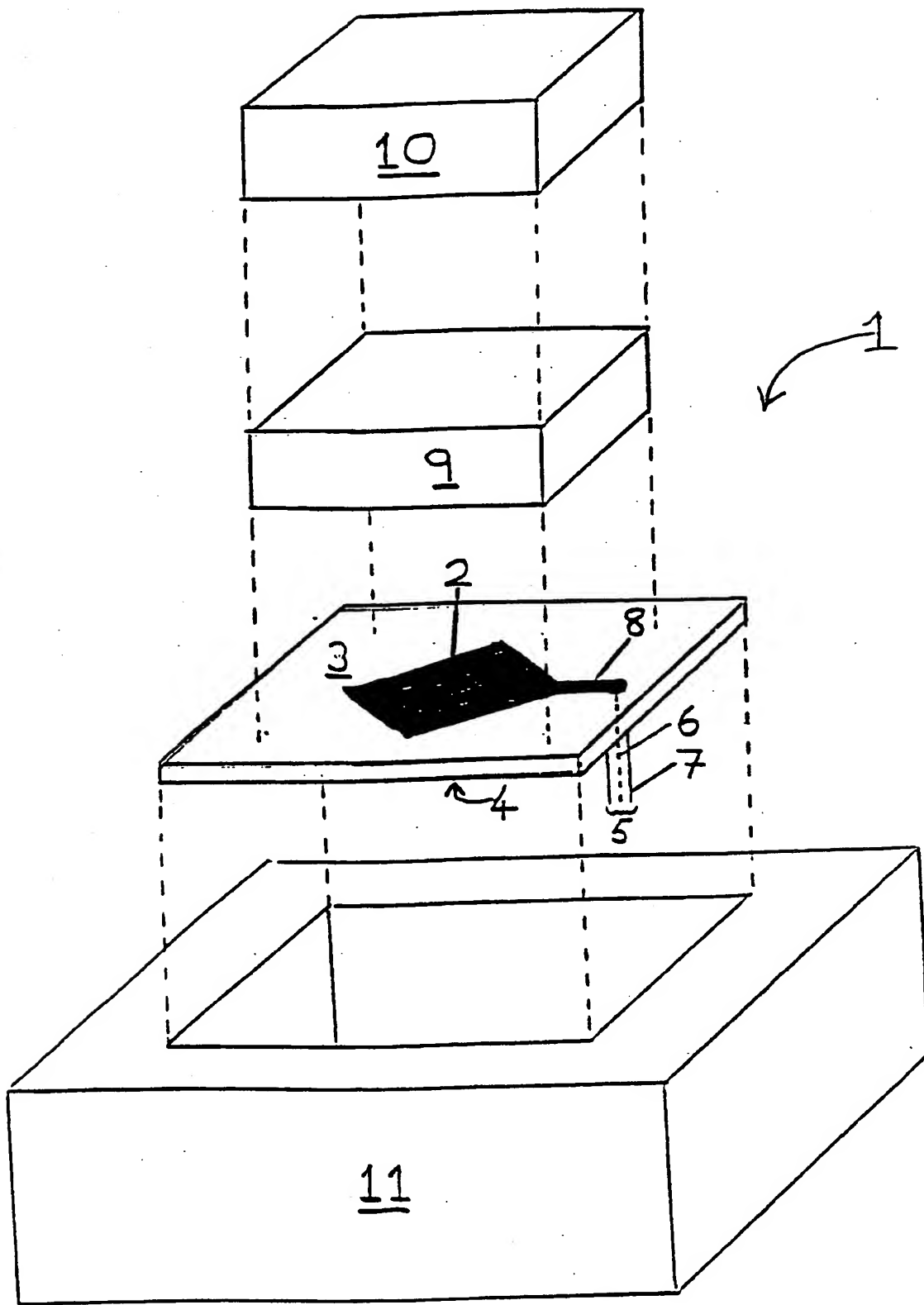


FIGURE 2

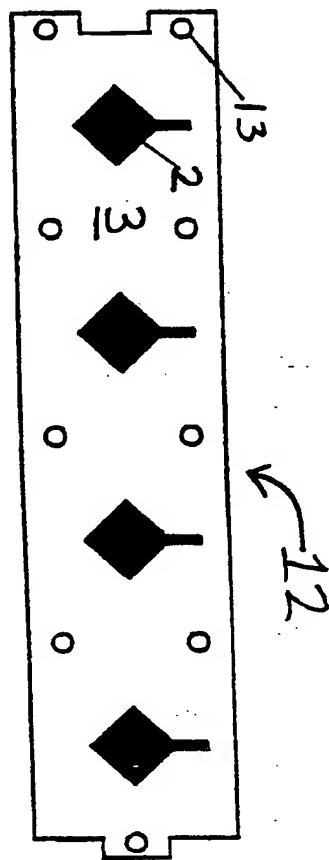


FIGURE 3a

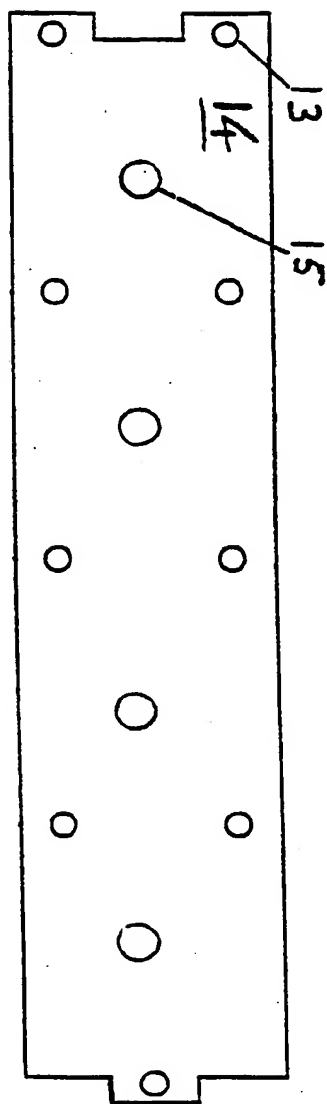


FIGURE 3b

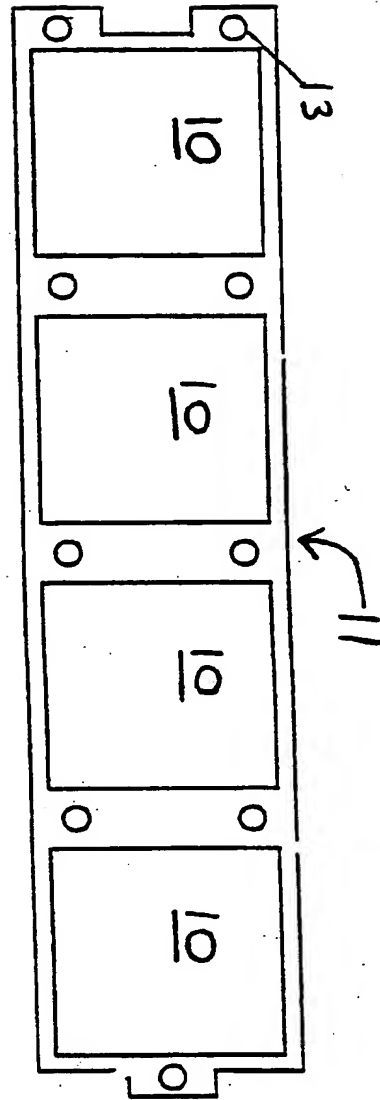
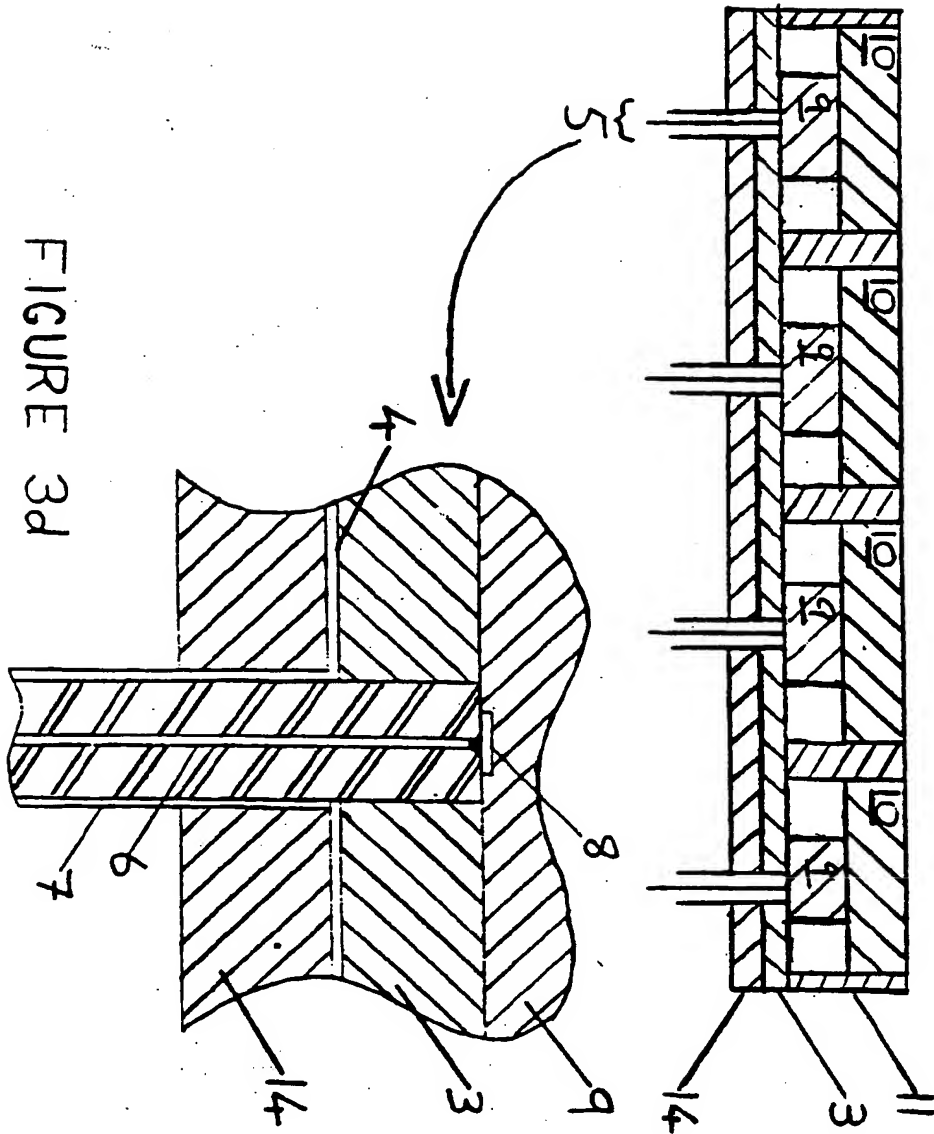


FIGURE 3c

FIGURE 3d



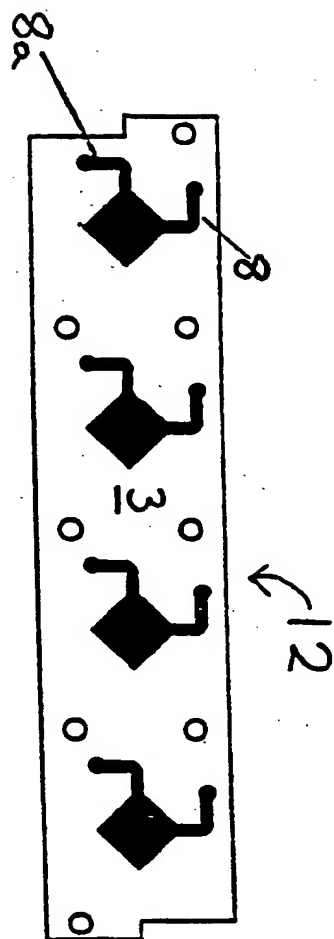
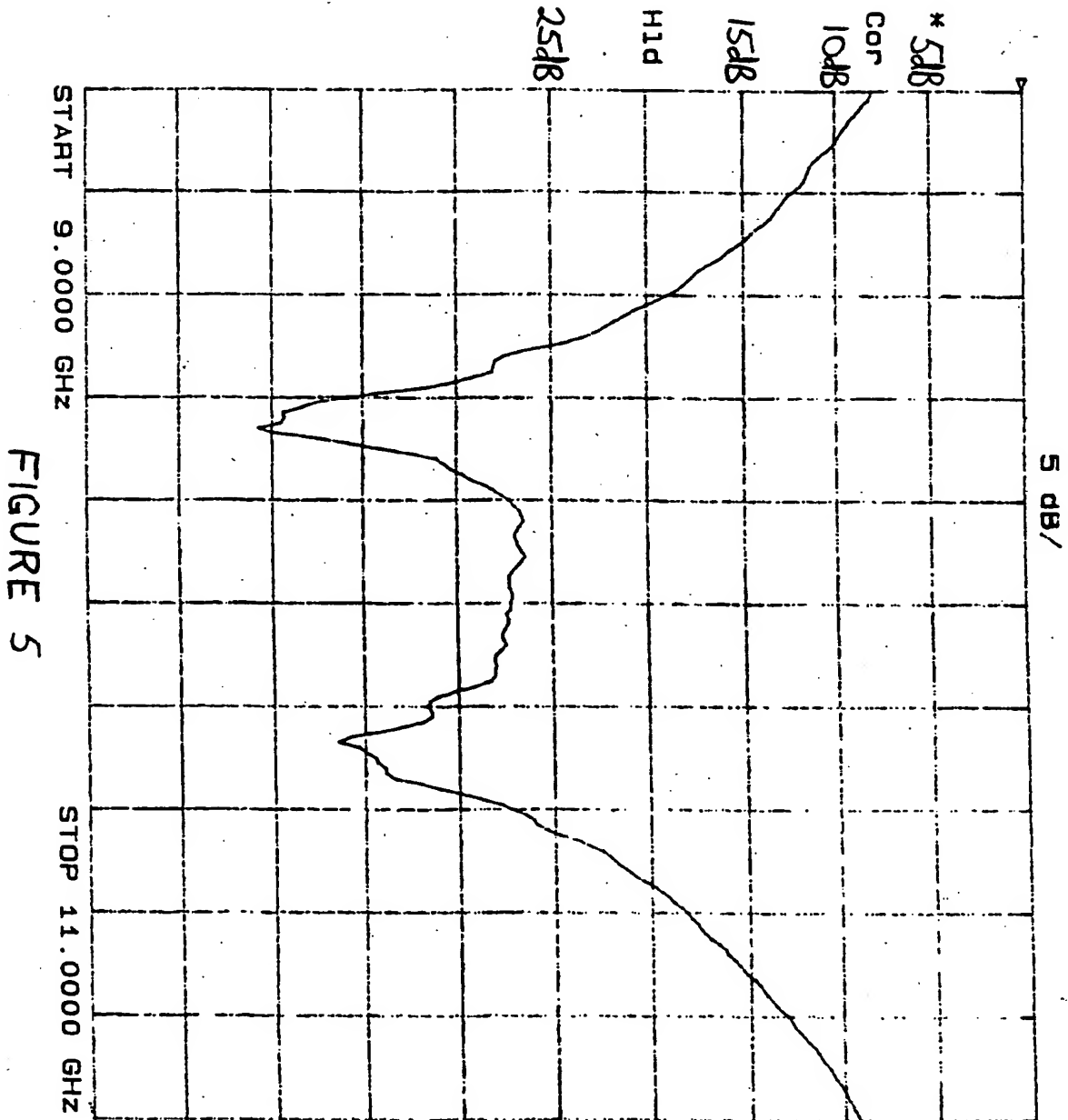
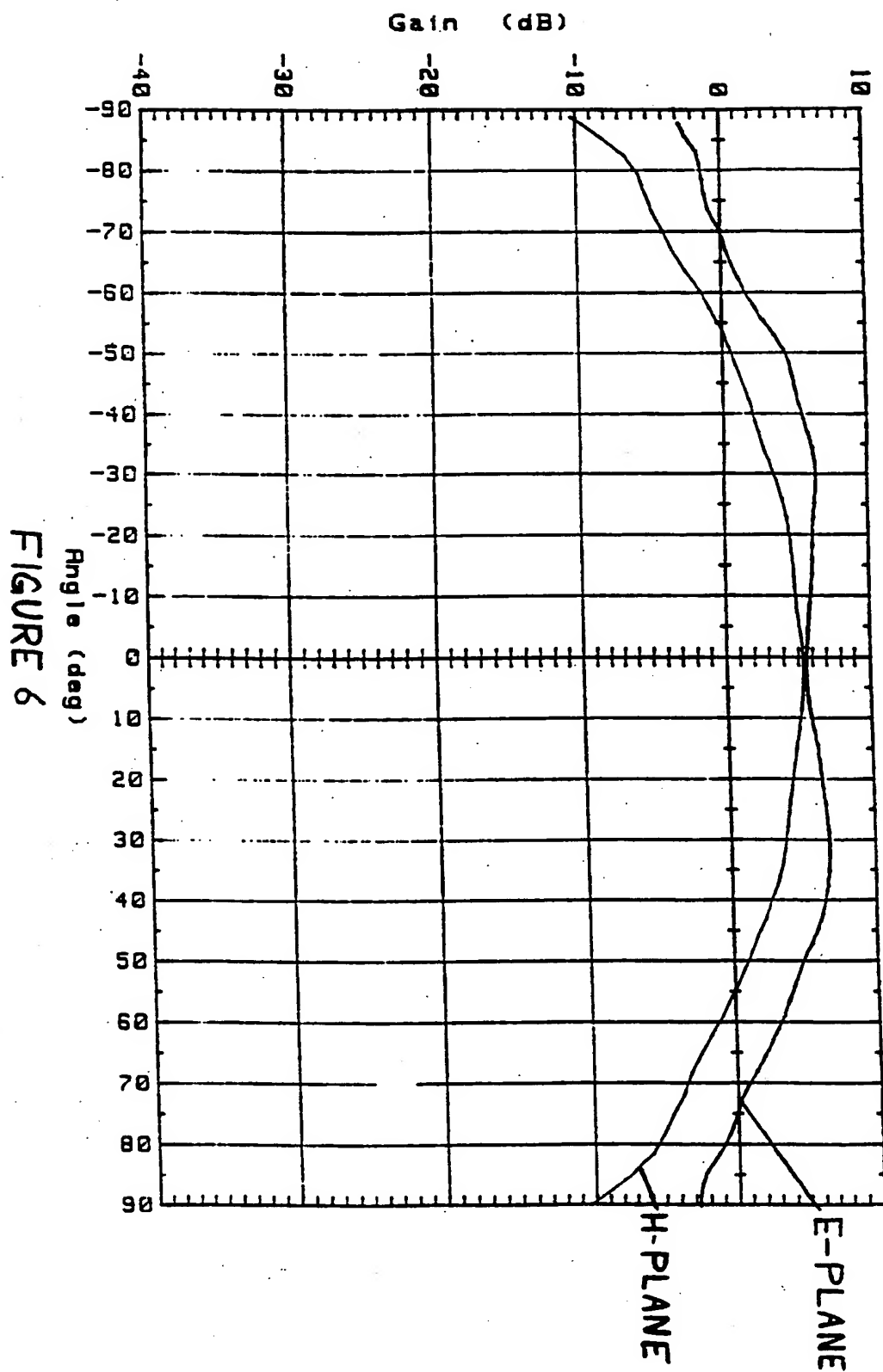


FIGURE 4







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## EUROPEAN SEARCH REPORT

Application Number  
EP 93 20 2597

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
Y	ELECTRONICS LETTERS. vol. 24, no. 18 , 1 September 1988 , STEVENAGE,GB pages 1156 - 1157 KRANENBURG ET AL. 'MICROSTRIP TRANSMISSION LINE EXCITATION OF DIELECTRIC RESONATOR ANTENNAS' * the whole document *	1,2	H01Q9/04 H01Q19/09
Y	RADIO AND ELECTRONIC ENGINEER vol. 48, no. 11 , November 1978 , LONDON GB pages 549 - 565 HALL ET JAMES 'Survey of design techniques for flat profile microwave antennas and arrays' * page 559, paragraph 5.7 - page 560; figure 19E *	1,2	
A	US-A-4 191 959 (KERR) * figures 1A,2,11 *	1-4	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
A	ELECTRONICS LETTERS. vol. 28, no. 6 , 12 March 1992 , STEVENAGE, GB pages 541 - 542 HAKKAK ET AL. 'GAIN ENHANCEMENT OF DIELECTRIC RESONATOR LOADED WAVEGUIDE ANTENNAS WITH DIELECTRIC OVERLAYS' * the whole document *	1,5-9	H01Q
A	GB-A-2 054 275 (EMI) * claims 1-6; figures 1A-2B *	1,6-9	
		-/--	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 6 December 1993	Examiner Angrabeit, F
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons ----- & : member of the same patent family, corresponding document	

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	WESCON TECHNICAL PAPERS vol. 28 , October 1984 , NORTH HOLLYWOOD US pages 356 - 357 HALL ET AL. 'MICROSTRIP PLANAR ARRAYS WITH DIELECTRIC SPHERE OVERLAYS' * the whole document * -----	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 6 December 1993	Examiner Angrabeit, F
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